CHAPTER 2

Literature Review

2.1 Introduction

Longan is an evergreen tree which belongs to the Sapindaceae family with many scientific names including *Dimocarpus longan* Lour., *Euphoria longana* Lam., *E. longan* Strand., *E. morigera* Gagnes., and *E. scanderns* Winit & Kerr. Its English common name is 'Longan', derives from a Cantonese name, which means "Dragon's eye". Its vernacular names in different countries is not similar include: 'Lamyai' in Thailand, 'Lam Nhai' in Laos, 'Kyet Mouk' in Myanmar, 'Nhan' in Vietnam, and 'Lengkeng' in Indonesia and Malaysia. Plants in the same family which are also of economic value, include rambutan (*Nephelium lappaceum* L.), and lychee (*Litchi chinensis* Sonn.; *N. litchi* Camb.; *Scytalia chinensis* Gaertn.; *D. lichi* Lour.) (Morton, 1987; Montoso Gardens, 2007). Longan is planting popularly in China, Thailand, Taiwan, India and Vietnam (Jiang *et al*., 2002). Longan is a type of tree in the network of sustaining agriculture in many Asian countries, either as a backyard crop or in large cultivated plantations (Tongdee, 2001). China is the biggest country in planted area and yield of longan, with the crop having undergone a rapid expansion in parallel with lychee since 1980. In 2000, China had 465,600 ha in longan planted area and total yield of fruit was about 608,500 Metric Tons (MT) (Huang *et al*., 2005). In 2001, Thailand had 57,261 ha in longan planted area and total yield was about 186,800 MT. In recent year, Thailand is becoming the main producer and exporter of longan in the world, fruit not only is sold as fresh but also drying and canning (Anupunt and Sukhvibul, 2005). In 2002, Taiwan had 12,258 ha longan planted area and total yield was 110,925 (Yen *et al*., 2005).

Longan is seen a type of traditional fruit of Vietnam and the major planting areas are in the southern provinces: Tien Giang, Ben Tre, Dong Thap, Vinh Long, Can Tho, Ba Ria Vung Tau; and the northern provinces: Lao Cai, Yen Bai, Thai Nguyen, Phu Tho, Son

La, Hung Yen and Thanh Hoa (FAO, 2004). In 2011, the Ministry of Agriculture and Rural Development (MARD) of Vietnam reported that total yield of longan fruit was 616,400 tons, increased 7.4% when compared with the year of 2010. In the north, longan trees cv. Long and cv. Cui have been commercially planting due to their fruit is big and their seed is small (80 to 100 fruits/kg). In the south is cv. Long and cv Tieu Da Bo, these cultivars have big fruit (80 to 90 fruits/kg) (FAO, 2004). In Vietnam, 'Long' longan flower blooms in February through March and the fruit matures from July to September in every year (Tuc, 1999; Dat, 2003). The differences in the times of flowering and fruit maturity are due to differences in rainfall and the temperature differences between day and night. The flowers are small and yellow brown. Growers in Vietnam have been using some chemical treatments by spraying to extend the fruiting season. Among them, chlorate and/or plant growth regulators are the most popular such as Fruitka Forlia (50% K_2O); Potassium chlorate (99.6%) and Potassium oxide; etc. Due to the demand of domestic consumers is high, longan fruit can bring more profit to producer in Vietnam as there seems to be no major climatic problems effecting the development of tree, flowering and fruiting in both the North and the South. There was a significantly increasing in exporting fresh fruit, drying and canning fruit to the southern China, Singapore and Hong Kong. Whereas, maintaining a high quality standard for above exported products must be carried on (FAO, 2004).

2.2 The fruit morphology of 'Long' longan

'Long' longan fruit is spherical shape to ovoid shape, growing in the panicle and the number of fruit can be up to 80 fruits per panicle. The fruit is big (average diameter of fruit is 2.9-3.0 centimeters and average weight is 11-12 grams per a fruit), bright brown color, small seed (average weight of a seed is 1.68 ± 0.27 grams), and thick flesh (the percentage of flesh per fruit weight is 63.0 ± 3.1%) (Hai, 2011; Hoan *et al*., 2001). The thickness of the pericarp was 0.69 ± 0.02 millimeters (mm), thickness of the flesh was 4.0 ± 0.6 mm, the soluble solids content was 18.97 ± 1.4 %, and the color of the fresh fruit when expressed as L* value (lightness) was 47.8 ± 2.1; a* value (redness) was 7.5 ± 1.1; b* value (yellowness) was 27.7 ± 1.4 (Hai, 2011). The flesh of fruit has white to off-white color, the seed of fruit has brown or black color and flesh is easy to separate from the seed, fruit has a sweet taste and juicy. It is middle in flavor and less acidic than litchi (FAO, 2004).

2.3 Harvest maturity

Longan fruits are non-climacteric and must be harvested when fully mature. The ripe fruit is darkening, smooth rind, the taste of fruit is sweet. Normally, harvesting is done twice at an interval of 7 to 10 days (FAO, 2004). On the other hand, fruit has to harvest when pericarp of fruit has yellow-brown color and flesh of fruit has optimum eating quality (Tuc, 1999). General guidelines for the time to harvest longan fruit are difficult to set due to the wide range of cultivars planted. Ripening may be defined by fruit weight, pericarp color, the concentrations of sugar and acid in flesh (Jiang *et al*., 2002). According to the experiences of Vietnamese farmers, the best harvesting time is the color of pericarp changes to bright color, smoother and the seed of fruit changes to black color. Another way for most longan fruits in Vietnam, maturity can be determined by Brix degree when Brix degree reaches 20-22 (Dat, 2003).

2.4 Harvesting method

The harvesting time of ‘Long’ longan will be started from the middle of July to the middle of September. Fruits are harvested in the morning or in the afternoon, avoid high temperature like at noon. The bunches of fruit on the trees are cut by a scissors and place immediately in the shade after harvest (Tuc, 1999). For sale, bunches are laid in the plastic baskets or sponge boxes with 5 or 10 or 20 kilograms of weight. At the bottom and on the top of baskets or sponges are lined with fresh longan leaves or soft papers.

2.5 There were some studies on storage of ‘Long’ longan fruit in Vietnam in recent years

The postharvest life of ‘Long’ longan fruit is limited by a decrease in visual appearance, a reducinng in organoleptic quality and the developing of disease. Water loses rapidly in fruit throughout the preservative period. At low humidity condition, visual appearance decrease to unacceptable levels because of pericarp dehydration and pericarp browning (Tuc, 1999; Hoan *et al*., 2001).

In Vietnam, most fruits are marketed in bunches on the fruit stalk and are consumed within 2-3 days after picking, without any postharvest treatments. Longan is transported by the trucks for a short distance transport or the cold container transporters for a long distance transport.

Sulfur dioxide fumigation with dosage was 0.5-3.5 g/m³ and stored at room temperature for 5 days. The above treatments were not suitable for extending storage life of 'Long' longan because of high postharvest losses (about 20%) (Hoan *et al*., 2001).

Dipping in benomyl solution at a concentration of 0.1% and then dried in the shade, after that packed in polyethylene bags (0.02 mm of thick) with 10-15 kilograms of weight per bag and put in carton boxes or bamboo baskets. Finally, stored in 3-5ºC; 90% relative humidity (RH) can be prolonged the 'Long' longan fruit storage life for 10-15 days (Tuc, 1999).

Dipping period was 5 seconds in chitosan coating solution at different concentrations, then dried in the shade; packed in 250 x 350 mm LDPE bags, 0.01 mm of thick, holed 20% surface of a bag. The result did not show any positive effects for 'Long' longan fruit (Hoan *et al*., 2001).

Fruits were dipped in sodium metabisulfite solutions at the concentrations from 0.1 to 0.9%, and then dried in the shade, after that packed in LDPE (0.01 mm of thick) and stored at room temperature for 5 days. The above treatments also were not suitable to extend the shelf-life of 'Long' longan fruit because of high postharvest losses including weight loss, fruit decay and extreme pericarp browning (more than 20%) (Hoan *et al*., 2001).

Fruits were dipped in carbendazim solution at a concentration of 0.2% for 2 minutes, dried in the shade, and then packed in 250 x 350 mm LDPE bags with 0.01 mm of thick. After that 'Long' longan fruit was kept at room temperature and at 10ºC. The results showed that longan fruit can be prolonged the shelf life with good quality for 6 days at room temperature and 20 days at 10ºC. Generally, postharvest losses were about 10% (Hoan *et al*., 2001).

Huyen and Thuy (2011) reported that coating longan fruit with 2% chitosan could reduce water loss and maintain the color, sensory quality and content of total soluble solids of the fruit and delayed fruit rot development as compared with other chitosan concentrations and control fruit for 20 days in storage. However, the percentage of fruit decay was high (about 11,4%).

Longan fruit cv. Long fumigated by SO_2 with dosage of 80g/100kg fruit for 20 min and stored at 5ºC for 28 days did not show fruit decay but high SO_2 residue about 44ppm (Thuy and Duyen, 2011).

Hai (2011) and Hai *et al*. (2011) concluded that dipping 'Long' longan fruit in 7.5% sodium metabisulfite solution for 10 min prevented pericarp browning and fruit decay, and maintenance of postharvest quality during the first 21 days for bunches and 28 days for individual fruits in storage at 5ºC. In addition, the SO_2 residue in the flesh of fruit after 7 days in storage was 0 ppm, and no residue was detected in the pericarp of longan fruit after 21 days in storage.

2.6 The popular longan cultivars in Vietnam

There are several longan cultivars in Vietnam, among them the most popular cultivars are Long; Cui; Duong Phen; Nuoc; Vinh Chau; Tieu (Dat, 2003). Among them, 'Long' cultivar has the highest economic value and nutrient values. The price of 'Long' longan was approximately from 40,000 to 55,000 Vietnam Dongs (approximately from 2 to 2.7 US Dollars) per kilogram in 2014. Together with 'Long' cultivar, the other longan cultivars in Vietnam which are introduced as follows:

'Cui' longan fruit is spherical shape, the pericarp is yellowish-tan in color. The average weight is 7-11 grams per a fruit, and the average thick of peel is 0.5 mm. The average rate between flesh and fruit is 58% (Tuc, 1999).

'Duong Phen' longan fruit is dark brown in color, small seed, thick peel and brittle, thick flesh, high sugar rate, sweet taste. Fruits are circle in shape and average weight is 7-12 grams per a fruit. The average rate between flesh and fruit is 60% (Tran, 1999).

'Nuoc' longan fruit is small (the average weight is 5.3-6.2 grams per a fruit), thin flesh, flabby flesh, high moisture and the seed separates difficultly from the flesh. The average rate between flesh and fruit is 58% (Tuc, 1999).

'Vinh Chau' longan fruit is big, green brow color, smooth peel, high water and the seed separates difficultly from flesh, and big seed. Although this cultivar has low values but it is very suitable with the land in southern Vietnam (Dat, 2003).

'Tieu' longan fruit is dark brown color, thick flesh, small seed, moderate sweet taste. The average weight is 10 grams per a fruit, and the average rate between flesh and fruit is 60% (Tuc, 1999).

2.7 Chemical composition of 'Long' longan fruit

'Long' longan flesh is very sweet taste. The total sugars are 20.5 ± 0.40% among them, the major sugars of fruits are sucrose, fructose and glucose. The soluble solids contents are from 18.97 ± 1.4 to 21.15±0.45% (Hoan *et al*., 2001; Hai, 2011), total acids are 0.09±0.06%, and moisture is 72.4% in 100 grams of flesh (Hoan *et al*., 2001). During storage, total sugar, reducing sugar and total soluble solids contents of longan fruits increased, pulp cell permeability decreased and flavour improved (Pan *et al*., 1996).

2.8 Some main causes affect postharvest quality and storage life of longan fruit

2.8.1 Pericarp browning

One of the main factors affects the marketable longan fruit is fruit rapidly browns pericarp within a few days after harvesting. After harvesting, the pericarp color of longan fruit is changed rapid as a result of desiccation through preservation at either too low or high temperature, and fruit rot always relates with pericarp browning (Apai, 2010). Fruit is browned due to associating with water loss, heating and chilling injury or disease (Pan, 1994). Fruit is browned as a result of the oxidation of phenolic compounds by endogenous polyphenol oxidase (PPO) (Jiang *et al*., 2002).

1) Polyphenol oxidase (PPO)

PPO is a copper associated enzyme with two binding sites for phenolic substrates (Apai, 2009). It often occurs in plant and is also found in seafood (Yoruk and Marshall, 2003). PPO is activated by releasing into the cytosol when plant tissues undergo physical damage such as bruising, cutting or blending (Apai, 2009). The occurring of browning enzyme is due to the oxidation by PPO, of phenolic compounds to quinones and their eventual polymerization to melanin pigments (Jiang *et al*., 2002; Yoruk and Marshall, 2003). The changes in ionization of prototropic groups in the active site of an enzyme at lower acid and higher alkali pH values may prevent proper conformation of the active site, binding of substrates, and/or catalysis of the reaction. The pH optimal pH for PPO activity is wide difference in plant but it often range from 4.8 to 8.0 (Yoruk and Marshall, 2003). In longan fruit, the optimum pH for maximal PPO action is 6.5 (Jiang, 1999). Temperature is another important factor markedly effects the catalytic action of PPO is temperature. It is well known that a decrease in the kinetic energy of the reactant molecules at low temperatures corresponds to a slower reaction (Yoruk and Marshall, 2003). The optimal temperature for the action of PPO in plant is different. Optimum temperature for the activity of PPO in longan fruit was 35ºC (Jiang, 1999; Yoruk and Marshall, 2003). At harvesting time, the action of PPO is low, and it augments a peak after long storage period (Wu *et al*., 1999). The impact of SO_2 fumigation on the overall quality of longan fruit cv. Shixia throughout cold preservation (4ºC) was evaluated. The result showed that the anthocyanin content in longan peel reduces and the rind colour was bettered after SO_2 fumigation (Han *et al*., 1999). Fresh longan production of the world markets are in competition and mostly depend on the quality e.g. fruit rind color, size, shelf life and also the safety of the fruits. The use of N-acetyl-L-cysteine and 4-hexylresorcinol, which are defined as GRAS (Generally Recognized As Safe) could be used to reduce rind browning (Sodchit *et al*., 2008). Although this situation is only a visual symptom and has no impact on flavor but color is deteriorated leading to fruit to sell at low price in markets and even fruit can not sell due to consumer prefers fruit with good visual appearance (Jiang *et al*., 2002).

2) Water loss

All fruits and vegetables are coated by a natural cuticle it is a barrier to moisture loss. However, some water vapor can move through the pores, cuticle and micro-cracks in the cuticle. Fresh fruits and vegetables are lost water leading to undesirable in the change of texture, negative effect to their eating quality. Firmness reduces and the texture becomes more flaccid. This negatively effects the visual appearance to cause the product losing its desirable fresh looking. During the process of waxing, a tightly adhering thin film of the coating substance is applied to the surface of the fruit. The wax coating blocks the pores in the cuticle, which significantly decreases the amount of water vapor loss. The longer produce is expected to be preserved, waxing importantly reduces loss of weight of fruits and vegetable. Application a thin layer of wax coating can decrease the loss of weight in product from 30 to 40% (Postharvest Handling Technical Bulletin, 2004).

Pericarp browning development was significantly related to water loss (Apai, 2010). Higher moisture loss from peel results higher peel browning and longer preservative period. Rind is lost water and rind browning expressed as browning index significantly correlate ($P < 0.01$). Rind is lost water leading to increasing of PPO action, and obvious decreasing in total phenolic and flavonoid contents, however the anthocyanin content does not change obviously. This result indicates that phenolic and flavonoid are the major substrates for PPO through desiccation-induced browning. Rind is lost water to cause significantly the increasing the action of POD which also plays an important role in desiccation-induced browning in the peel of longan fruit. Rind is lost water to cause significantly the increasing in peel pH, which resulted in changes in anthocyanin structure and color, the degradation of anthocyanin became easier (Apai, 2009). Plastic bags reduce useful water loss (Su and Yang, 1996) and lead to the longest postharvest life (Zhou *et al*., 1997). Rapid water loss from the pericarp through storing is decreased at 85-95% humidity. At low relative humidity (RH) visual appearance decreases to unacceptable levels because of peel dehydration and browning. At higher RH the peel suffered water soaking and disease (Drinnan, 2004). Chitbanchong *et al*. (2009) reported that the surface cracking is also impair the physiological function of the cuticle and augmenting permeable moisture, which can cause water soaking at the inner side of the rind. Water loss from fruits and vegetables leads to the activation of PPO and treatments to decrease desiccation also decrease browning (Su and Yang, 1996).

3) Chilling injury

Fruits and vegetables have the original tropics to injure susceptibly chilling, which is a type of physiological injury that happens at low temperatures. The amount of chilling injury (CI) is dependent upon the temperature and period of exposure to the low temperature. It often happens at 13ºC (56 ºF) and 0ºC (32ºF), dependent upon crop. At low temperatures, decreased kinetic energy of the reactant molecules results in a reducing in both mobility and "effective collisions" necessary for the formation of enzyme-substrate complexes and their products (Apai, 2009). The symptoms of CI in longan peel are water-soaking or dried rind and darkened rind through storing period (Tongdee, 2001; Jiang *et al*., 2002), CI and water loss positively correlated (Boonyakiat *et al*., 2002). Waxing decreases severely CI and permits for preservation of CI-sensitive commodities at slightly lower temperatures without incurring damage (Postharvest Handling Technical Bulletin, 2004).

Jaitrong *et al*. (2006) studied CI development in longan when fresh longan fruit (cv. Daw) with 0.5 cm pedicels are laid in cardboard boxes and storing at 5±1°C, 90±1% RH. CI symptoms of water soaking and/or browned areas on the rind appear on the inner side of rind after 6 days storing and on the outer side of whole fruit within 14 days. Both sides of the peel became browning in color. During CI there was an increase in the activity of PPO and electrolyte leakage and decreases in total phenolic compounds and protein content. High performance liquid chromatography - photodiode array (HPLC-PDA) analysis of the methanol extracts showed a very large number of phenolic compounds that were similar in both cultivars. The main classes of phenolic compounds were tentatively identified as ellagic acid and flavone glycosides as well as a set of unknown compounds. The primary flavones in longan pericarp were quercetin and kaempferol. Microscopic anatomy of CI pericarp showed flaking of cuticle damage flaking of the cuticle, damage trichomes surface and parenchyma cell walls in the mesocarp. Separation and dissolution of the middle lamella and cell walls was evident resulting in a lack of cellular adhesion when assessed by light microscope (Jaitrong, 2006). Apai (2009) concluded that longan fruits kept at 5ºC showed more reduction in chilling injury than at 2ºC.

2.8.2 Respiration rate and ethylene production

Longan fruit is non-climacteric, harvested only when it is mature and has attained acceptable eating qualities. Rates of respiration range from 10 to 16 milliliters (ml) CO_2/kg/hour and 2 to 6 ml CO_2/kg/hour at 22ºC and 5ºC, respectively. Ethylene evolution ranges from undetectable to trace, immediately after harvest (Tongdee, 2001). Longan fruit produces relatively low levels of ethylene after harvested (< 2.3 µ/kg per h) which have been measured in combination with infecting fungi (Shi, 1990). Moderate to high ethylene production rates have also been recorded coincidentally rind desiccation and after storing at high temperature of 26-32ºC (Pan *et al*., 1996). Shi (1990) found that the rate of ethylene of longan fruit preserved at 1 or 4 ºC maintaining relative constancy for 30 days after stabilizing on the first day. An increasing in the rate of ethylene production after 30 days relates with decay. Waxing produces a modified atmosphere inside the product in which the oxygen content is reduced and the carbon dioxide content is augmented. This result leads to reducing in the rate of respiration of product and an increasing in storing period. An extended preservative time allows an extending in the marketing period for the crop (Postharvest Handling Technical Bulletin, 2004).

2.8.3 The development of microorganism and fungus

Fruit decays rapid after harvesting, fruit decay mainly caused by the growth of saprophytic fungi on the fruit surface and dehydration of the rind; the shelf life of fruit at room temperature (30ºC) is only two or three days. The most important microorganisms are *Botryodiplodia* sp., with dark-grey myeclia growing saprophytically on the fruit surface, and yeasts, *Saccharomyces* sp. The latter gain entry through the stem end of insect-pierced fruit, causing aril disintegration; wherever there is free moisture, the yeast forms a milky slimy mass oozing from the fruit surface. At low RH deterioration by microorganisms is reduced, but the fruit losses its freshness. The rind turns dry and brittle, although the aril may still be acceptable. The rot problem is reduced but not entirely eliminated by cold storage. Shelf-life can be extended for two days at 18ºC. At 12ºC, 20% of fruit rotted after one week and all fruits rotted after two weeks (Tongdee, 2001). About 106 species of microorganism have been isolated from longan fruit, comprising 36 bacteria, 63 mold and 7 yeast species (Lu *et al*., 1992). Major postharvest pathogens of longan fruit are *Enterobacter* sp., *Acinetobacte* sp. (Lu *et al*., 1992) for bacteria; and *Botryodiplodia* sp. (Jiang, 1997), *Penicillium* sp., *Rhizopus* sp., *Alternaria* sp. (Lu *et al*., 1992), *Lasiodiplodia* sp., *Cladosposporium* spp. (Sardsud *et al*., 1994) for mold. Product is waxed to create a barricade for resisting the attacking of pathogen of mold and bacteria into product. Postharvest pathogens typically require a film of free moisture on the product's rind to develop. Coating establishes a hydrophobic (non-water compatible) surface which is not conducive to the growth of pathogen. Addition of fungicide in waxes can also be done for providing the protected addition protection resist decay (Postharvest Handling Technical Bulletin, 2004).

2.9 The application of wax coating, oxalic acid and sodium hypochlorite for fruits and vegetables storage

2.9.1 Wax coating

Most fruits and vegetables grow a waxy coating on the epidermis as they ripe into plants. Wax grows when the fruit attains 2/3 of its development. However the natural waxy coating does not provide much protecting resist losing water and high perspiration. Therefore to protect the vital elements of fruits and vegetables owing to their growing importance these days a process of waxing evolved (Lazar, 2010).

Waxing is primarily done to prevent moisture loss, to decrease rate of transpiration, to replace natural wax, to protect from bruising during shipping and other physical damages, to increase shelf life, to protects from mold growth, to maintain attractiveness, to increase freshness, to prevent shriveling and losing weight in fruit and vegetable (Thirupathi *et al*., 2006; Lazar, 2010).

Wax is an ester along chain aliphatic acid with chain aliphatic alcohol. Waxes are the esters formed from a fatty acid and a high molecular weight alcohol. Waxes removed in washing and cleaning operations. One of the roles of wax is to help reducing the water loss and rates of respiration during handling and marketing (Thirupathi *et al*., 2006). Commercial fruit wax had sufficiently low non-condensable gas permeability to account for large reductin in the rate of respiration of coating fruits (Hagenmaier and Shaw, 1992). Waxing decreased moisture loss in 'Tongbi' longan fruit more than 2 days at ambient temperature (Shi, 1990). Paraffin was replaced by carnauba wax (natural wax) for storing cassava root (Sargen *et al*., 1995). Orange, lemon and grape fruit are coated by Fruitex, Britex-561 and SB 65 wax improved their inner appearing by giving additional shine to the fruit surface, reduced weight loss and kept the fruits firmer, thus marinating their fresh look. In addition, wax coating reduced rates of respiration and ethylene production, thus delayed senescence (Farooqi *et al*., 1988). Hu *et al.* (2011) reported that Sta-Fresh 2952 wax (60g/l) was more effective on pineapple fruits in alleviating chilling injury, which delayed the changes in firmness, flesh color, weight loss and soluble protein content; decreasing titratable acidity, TSS, cell membrane permeability, and malondialdehyde content when compared with those in control. This waxing also improved total sugars, and the contents of ascorbic acid in pineapple fruits.

Waxing tomato fruits allow reducing their storage temperature, protecting them from chilling injury and maintaining their quality and delaying in weight loss, color development and ripening (Torres *et al*., 2009). According to the research of Sornsrivichai *et al*. (1990), waxing of Xiang Sui and Pien Pu pear slowed down the rate of ripening by retarding loss of flesh firmness and the change of skin color; rate of decrease of malic acid and chlorophyll content was also slowed down at low temperature with waxing treatment; and reduced weight loss at all storage temperatures. Orange fruit cv. Blood Red was coated in 5% bees wax containing 0.5% benlate improve generally quality and prolong the postharvest life of fruit (Shahid and Abbasi, 2011). BQE-625 (Michel Emulsion - USA) wax at concentration of 94% (waxing time was 20 seconds) was more effective in maintaining the good quality for 15 days in storage on Vietnamese mango fruits cv. Cat Hoa Loc; waxing at concentration of 91% for 30 and 46 seconds could remain the marketable quality for 33 and 20 days on Vietnamese tomato and cucumber fruits respectively (Hung, 2008).

2.9.2 Oxalic acid

Oxalic acid (OA) is a popular ingredient in plant such as carrots, asparagus, broccoli, garlic and spinach (Whangchai *et al*., 2006; Suttirak and Manurakchinakorn, 2010). It is the chemical compound with the formula $C_2O_2(OH)_2$ or HOOCCOOH. OA inhibited rind browning as a result of inhibiting the action of PPO in longan fruits (Boonin *et al*., 2006; Whangchai *et al*., 2006). OA is a strong acid to inhibit browned situation. The inhibiting pattern on catechol-PPO model system appeared to be competitive. When the PPO is combined with OA, the action is not recovered via dialysis (Son *et al*., 2000). Zheng and Tian (2006) reported that OA can efficiently manage the rind browning of litchi fruit through postharvest preservation because of increasing of membrane integrity, inhibiting of anthocyanin degradation, declining of oxidation, and maintaining of relatively low peroxidase action in the fruit. OA has been indicated to suppress apple browning and was previously shown as a potential anti-browning agent for apple PPO (Yoruk *et al*., 2002). Saengnil *et al*., 2006 demonstrated that soaking litchi fruits cv. Hong Huay in the solution of OA at concentration of 10% for 15 min was the most effective in controlling browning. Inhibiting of PPO by OA was due to its binding with copper to form an inactive complex, and the inhibiting is characterized as noncompetitive. OA is a more potent inhibitor of PPO compared with other structurally related acids (Yoruk and Marshall, 2003). Whangchai *et al*. (2006) also reported that OA at concentration of 5% is more potent anti-browning agent compared with other acids on longan fruit cv. “Daw”.

OA inibits browning by lowering the pH of the product to minimise PPO activity. At pH values below 4, PPO has little acitivity because of the loss of copper at the active site. Effectiveness of OA in retarding discoloration is combined with copper chelation at the PPO activity site. The OA is weak organic acids widely attended in plant tissues (Suttirak and Manurakchinakorn, 2010). Use of organic acids in combination with chitosan to replace sulphur compounds or strong mineral acids, brought an alternative technology for the inhibiting in browning of lychee fruit (Joas *et al*., 2005).

Organic acid has been reported often for its efficiency in inhibiting browned action in fresh-cut fruit and vegetable and have generally recognized as safe (GRAS) status. However, following to the Thailand Food and Drug Administration, intake of OA should be limited to 378 mg per 1 kg body weight per day, to inhibit the decreased absorption of dietary minerals such as calcium, magnesium and potassium (Suttirak and Manurakchinakorn, 2010).

2.9.3 Sodium hypochlorite

Sodium hypochlorite (SH) normally is known as bleaching or bleaching liquid, it is often used as a disinfecting or a bleached agents. US Government regulations (21 CFR Part 178) permit the contacting surface of food to sanitize with solution contained bleach, that does not exceed 200 parts per million (ppm) available chlorine. It is effective against many bacteria and some viruses (Wikipedia, 2013). SH has been approved (registered) for use by the U.S. Environmental Protection Agency (Suslow, 2000). Many kinds of postharvest decays affect fresh fruits and vegetables and may be caused by fungi or bacteria. The use of chlorine solutions such as calcium or sodium hypochlorite as disinfectants is known as chlorination and is used to prevent microbial inoculation (Hong and Gross, 1998). Traditionally sanitizer such as chlorine solution has been used to rinse fresh fruits, with the main objective of reducing microbial contamination, therefore extending product shelf life. The chlorination process usually consists on adding chlorine (Cl_2) or sodium or calcium hypochlorite to wash water at concentrations between 50 and 200 ppm and for a contact time of 1 to 2 min (Bachmann and Earless, 200; Beuchat, 1998). Chlorine has no residual affect (Sawyer, 1978). Sodium hypochlorite (<1%) rarely produces necrosis or significant mucosal injury (CHAPD, 2007). Furthermore, the dip treatments were performed with undamaged fruits to avoid any seeping of SH into the edible fleshy part of litchi. The residual chlorine level was analysed and found to be negligible even in the pericarp ($Cl^- \leq$ 0.06%). As far as fruit-pulp is concerned Cl^- level was found to be further reduced ($\leq$ 0.01%). Thus, treated fruits can be considered as safe (Kumar *et al*., 2012). The use of chlorination presents one of the few chemical options to help manage postharvest decay. When used in connection with other proper postharvest handling practices, chlorination may be an effective and relatively inexpensive postharvest decay control method in fresh fruits and vegetables (Boyette *et al*., 1993). Postharvest decay may be caused by either fungi or bacteria, although fungi are found more often than bacteria in both fruits and vegetables (Boyette *et al*., 1993). SH was used to treat because of it is fungicidal property (Cerioni e*t al*., 2009). Hot water dip with sodium hypochlorite (200 ppm) at 52°C for 3 to 4 min was recommended for fungal disinfection of mango fruit (APEDA, 2007). The use of sodium hypochlorite as disinfectants is known as chlorination and is used to prevent microbial inoculation. Sodium hypochlorite also has no residual effect, and therefore, fresh produce exposed to pathogens after treatment remains susceptible to re-infection (Sawyer, 1978). The active ingredient of most liquid household bleach, sodium hypochlorite, is used commonly when the scale of postharvest chlorination is limited (Boyette *et al*., 1993; Suslow, 2000). Chlorine concentration of about 55 to 70 ppm at pH 7.0 with water temperature of 40ºC is recommended to sanitize most fruits and vegetables (Boyette *et al*., 1993). The primary uses of chlorine have been to inactivate or destroy pathogenic bacteria, fungi, viruses, cysts, and other propagules of microoganisms associated with seed, cutting, irrigation water farm or horticultural implements and equipments. Chlorine has been routinely used to treat postharvest cooling water, in postharvest treatments. In the past, maintaining wash tank and flume concentration of 3,000 µg/ml for tomatoes and 6,000 µg/ml for citrus were recommended to control decay (Suslow, 2000). Suslow (2000) also reviewed that published research on postharvest efficacy and proper management of chlorine for specific fruits and vegetables has been largely focused on tomato, citrus, potato, apple, pear, carrots, yam, sweet potatoes, strowberry, peach, iceberg lettuce, saparagus, cucumbers, peppers, sweet corn, mushroom, and minimally processed fresh vegetable. Hendrix (1991) reported that sooty blotch caused by *Gloeodes pomigena* and flyspeck caused by *Zygophiala jamaicensis* were removed from apple fruit with a postharvest chlorine dip. A 5 to 7 minutes dip in 500 ppm of chlorine in the dump tank of a commercial packing line, followed by brushing and a fresh water rinse, reduced the incidence of sooty blotch froom 100 to 0%, and flyspeck from 100 to 27%. *Botrytis cinerea* is a fungal pathogen that greatly reduces the postharvest quality of rose flowers. A postharvest dip in 200 ppm SH for 10 seconds at 20ºC provided the greatest control of *B. cinerea* on 'Akito' and 'Gold Strike' flowers. Applying SH prior to 3 or 5 days commercial shipment also provided the most consistent disease control for a wide range of rose cultivars as compared to conventional fungicide treatment (Macnish *et al*., 2010). Hong and Gross (1998) reported that pericarp firmness of tomato slices from fruit that had been treated with 1.05 % SH for 60 seconds was less than one-half the firmness of water-treated controls and lower than the other SH treatments after 12 days of storage, pericarp firmness of slices was lower for all treatments than for untreated control. In addition, the differences in electrolyte leakage between control fruit and fruit treated with 1.05 % SH for 60 seconds were 14.2, 25.6, and 25% at 4, 8, and 12 days respectively. Marangoni *et al*. (1995) and Yu *et al*. (1996) also found that for tomato, a range of 0.105 to 1.05% SH is commonly used with washing or dipping for 1 to 3 min to sterilize the surface of fruit before experimentation. Litch fruits (cv. Shahi and China) dipped in SH (0.2% for 4 min at 52°C), reduced microbial load to below detectable limits. Shelf life of processed 'Shahi' and 'China' cultivars at 4°C were 45 and 30 days respectively, whereas, unprocessed fruits spoiled within 15 days (Kumar *et al*., 2012). Kim *et al*. (2007) reported that water washed fresh-cut cilantros coriander was the first treatment to show decay symptoms on all of the replications, starting on day 4, and samples treated with SH had no decay at this stage. Hot water dip with 200 ppm SH at 52°C for 3 to 4 min was recommended for fungal disinfection of mango fruit (APEDA, 2007). Ukuku (2006) reported that using 200 ppm of hypochlorite solutions reduce 2.7, 0.38, 2.7 and 1.8 log unit for total bacterial, *Pseudomonas* spp., yeasts and moulds, and lactic acid bacteria counts in cantaloupes respectively. Beltran *et al*. (2005) found that after 13 days in storage at 4°C the microbial loads increase but the chlorine washed sample reduce final microbial count by 2.7 log unit on fresh-cut iceberg lettuce when compared to the control. Through cold storing, strawberry was pre-washed in 200 ppm SH indicates lower microbial loads than untreated, ultrasonicated, UV-C irradiated or water-washed sample (Alexandre *et al*., 2012). Fresh-cut cilantro was treated with SH shows significant reduction in initial aerobic plate count when compared with washing by tap water alone (Kim *et al*., 2007).

2.10 Effect of low temperature storage on quality of longan fruit

Longan fruits cvs. Daw, Seechompoo and Baew Kiew were stored at 1, 5 and 10ºC for 14 days. The analysis results showed that during storage at 1ºC, all longan cultivars showed chilling injury symptoms. The L* values of the outer and inner skins were decreased, whereas the pH values, the percentage of moisture loss and the skin electrolyte leakage were increased higher than the fruits those stored at 5 and 10ºC. At 5ºC temperature, the longan fruits also showed chilling injury symptoms but these were happened on the later stage of storage. The inner skin color and the skin electrolyte leakage could be used as indicators of chilling injury in longan fruit (Boonyakiat *et al*., 2002). Hydrocooling is the most common precooling method used. Precooling removes field heat and supplies efficient manageable temperature through subsequently container shipment of fruit for export. SO_2 fumigation and precooling are two of the most critical control points in the handling steps (Tongdee, 2001). According to the report of Apai (2009), the temperature at 5 ºC was the most consistent temperature for storing and was able to delay browning as a result of less severe chilling injury. Longan fruit stored at 4ºC continuously decreases in respiration (Zhou *et al*., 1997), and low temperature therefore efficiently prevents the respiration of longan fruit (Tongdee, 2001).